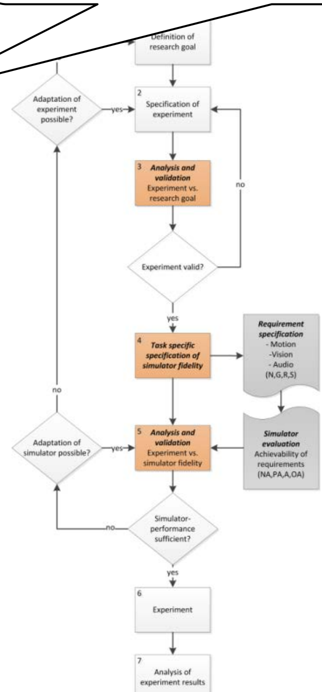
Objective Motion Cueing Test for Driving Simulators

Martin Fischer, Andreas Seefried, Carsten Seehof

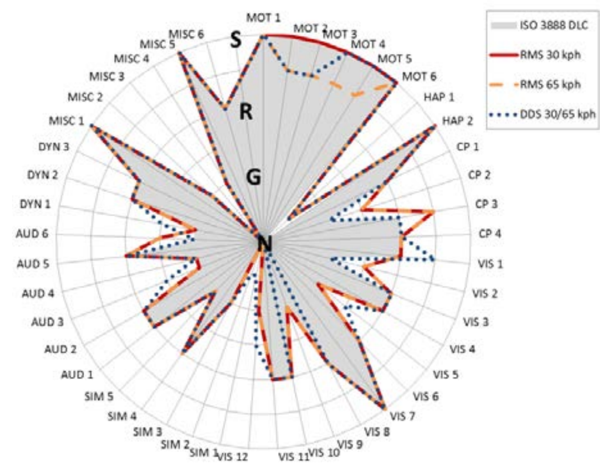
DSC 2016 Europe VR

Looking in the rear mirror…

Is your simulator appropriate for my research?



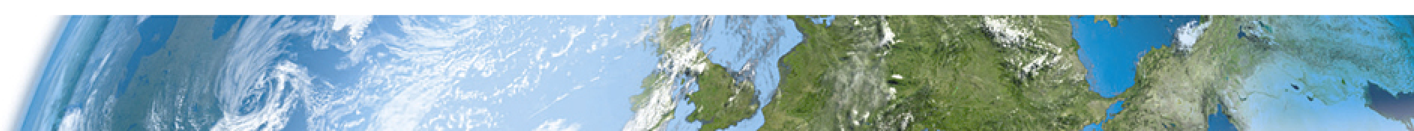
Well, it depends…



How to evaluate a simulator?

→ A Task-oriented Catalogue of Criteria for Driving Simulator Evaluation

Fischer et al, DSC 2015



Taking the next step…

Is your **motion base** appropriate for my research?

Well, it depends…

- How to evaluate the performance of a motion base and the correspondign motion cueing algorithm?
  - By technical specification & performance characteristics?
    → Is this sufficent and useful information?
  - By objective measures?
    → Are there overall objective measures?
    → For all technical and human-related aspects?
  - By subjective criteria?

Reprise – Is something better than nothing?

A motion cueing test with vague and/or subjective criteria is a complex way to seperate „bad“ motion from „very bad“ motion

→ nothing is gained

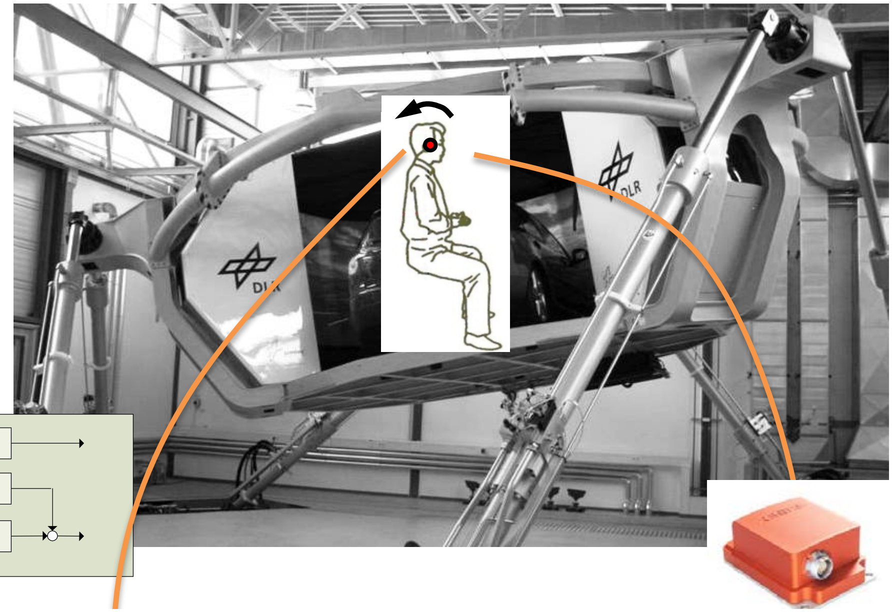
An **Objective Motion Cueing Test** with clear objective criteria may lead to true „High fidelity“

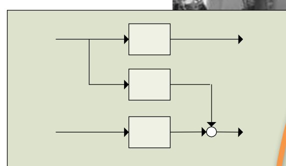
→major leap forward

Objective Motion Cueing Test Plan - Is Something Better Than Nothing?
4thHuman-Centered Motion Cueing Workshop, Delft, May 18, 2009
Eddy van Duivenbode, Bosch Rexroth

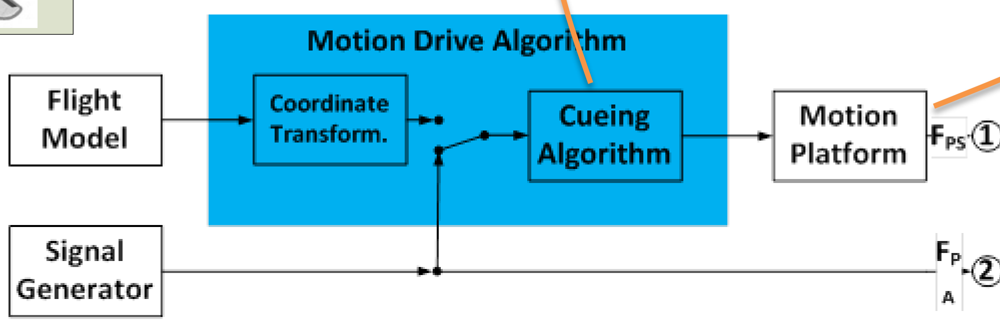
➡ The Objective Motion Cueing Test (OMCT) was included in 2009 in the ICAO standard 9625, Manual of Criteria for the Qualification of Flight Simulation Training Devices

Objective Motion Cueing Test (ICAO)





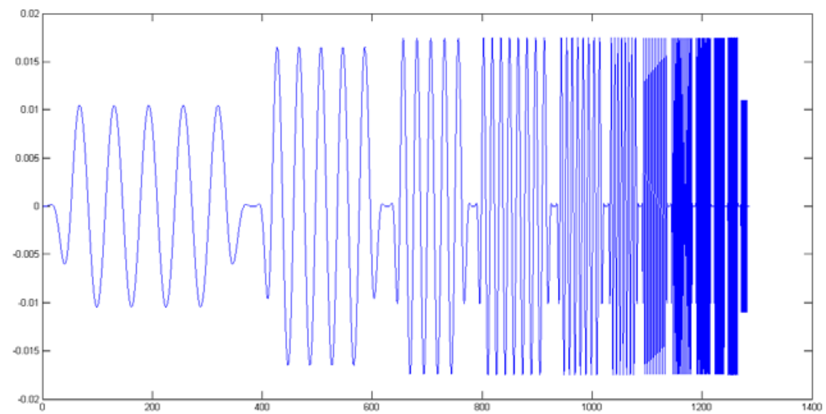
Point of rotation = position of „**I**nertial **M**easurement **U**nit“



OMCT Test specification (1/2)

Aircraft Input Signal \ Simulator Response Output	Roll	Pitch	Yaw	Surge	Sway	Heave
Roll	3				4	
Pitch		1		2		
Yaw			5			
Surge		7		6		
Sway	9				8	
Heave						10

Sinusoidal signal with 12 sub-sequences



Desired simulator response output

Gain = 1, Phase = 0 for direction motion response
Gain = 0 for coupled motion response

OMCT Test specification (2/2)

Translational input signals

No.	w [s^{-1}]	f [Hz]	A [ms^{-2}]
1	0,100	0,0159	1,0
2	0,158	0,0251	1,0
3	0,251	0,0399	1,0
4	0,398	0,0633	1,0
5	0,631	0,1004	1,0
6	1,000	0,1591	1,0
7	1,585	0,251	1,0
8	2,512	0,399	1,0
9	3,981	0,633	1,0
10	6,310	1,004	1,0
11	10,000	1,591	1,0
12	15,849	2,515	1,0

$$f_{x/y/z,PA}(t) = A \cdot sin(\omega t)$$

Rotatory input signals

No.	f [Hz]	A [deg]	Aw [deg/s]	Aw^2 [deg/s^2]
1	0,0159	6,000	0,600	0,060
2	0,0251	6,000	0,948	0,150
3	0,0399	3,984	1,000	0,251
4	0,0633	2,513	1,000	0,398
5	0,1004	1,585	1,000	0,631
6	0,1591	1,000	1,000	1,000
7	0,251	0,631	1,000	1,585
8	0,399	0,398	1,000	2,512
9	0,633	0,251	1,000	3,981
10	1,004	0,158	1,000	6,310
11	1,591	0,100	1,000	10,000
12	2,515	0,040	0,631	10,000

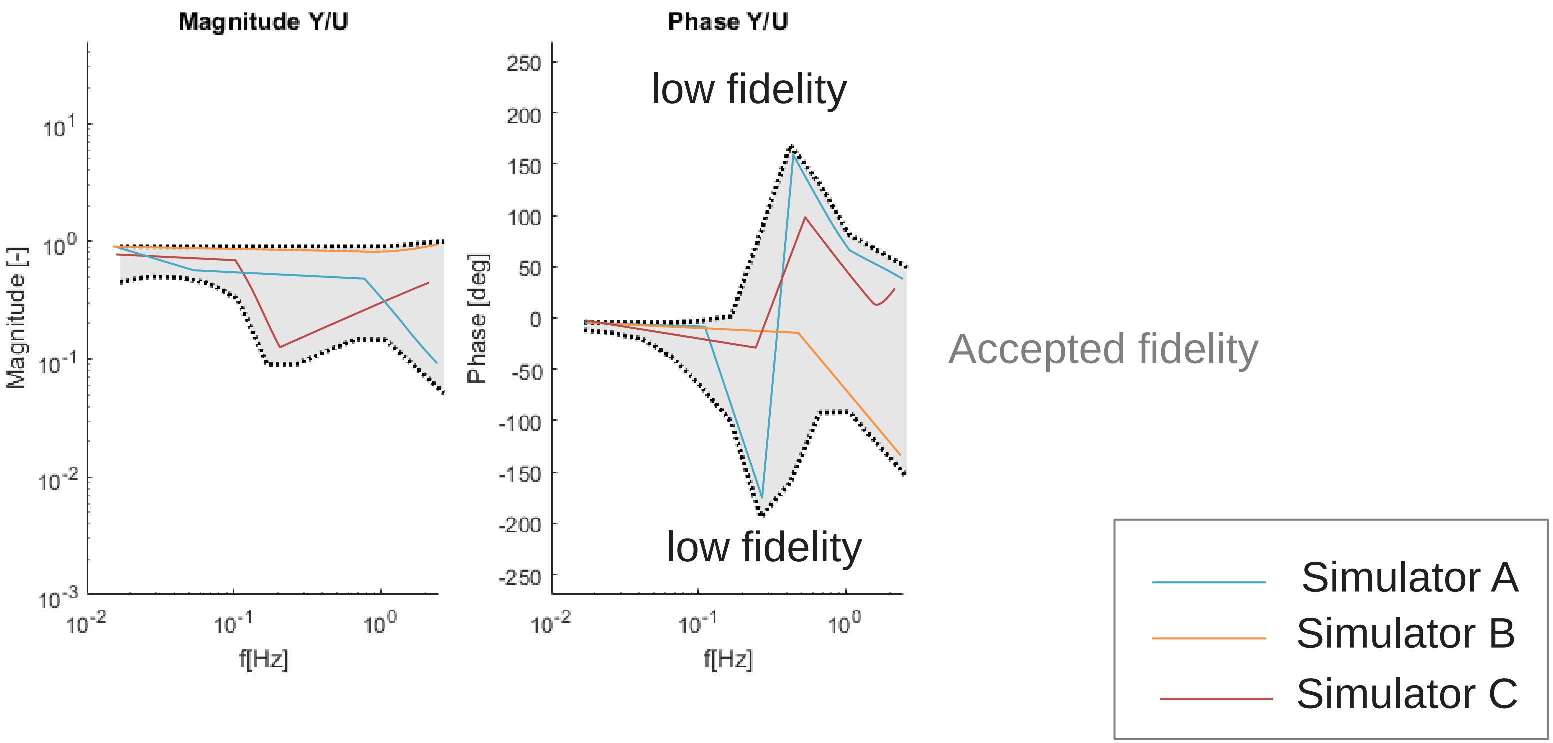
$$\mathrm{A} \cdot \sin(\omega t)$$

$$\mathrm{A}\omega \cdot \cos(\omega t)$$

$$-\mathrm{A}\omega^2 \cdot \sin(\omega t)$$

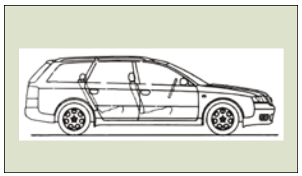
Criteria for level-of-fidelity

- Gain and phase corridor for OMCT test 6 (response to surge aircraft input)

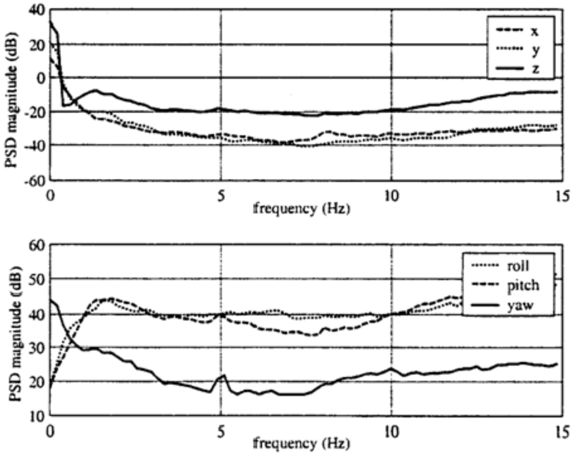


OMCT adaptation for Driving Simulation

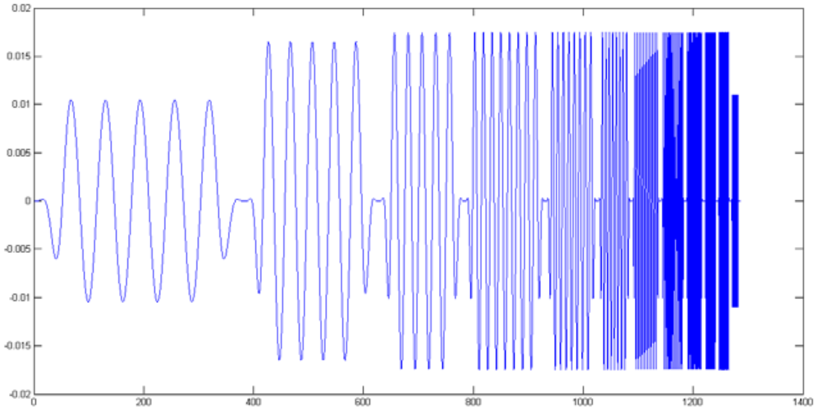
- Dynamics



Test specifications remain the same (i.e. identical input signals in frequency and amplitude)



Source: Reymond, G.; Kemeny, A.: Motion Cueing in the Renault Driving Simulator. In: Vehicle System Dynamics, Bd. 34, S. 249–259 (2000).



Additional tests for parasitic motion response

Aircraft Input Signal / **Simulator Response Output**

	Roll	Pitch	Yaw	Surge	Sway	Heave
Roll	3				4	
Pitch		1		2		
Yaw			5			
Surge		7		6		
Sway	9				8	
Heave						10

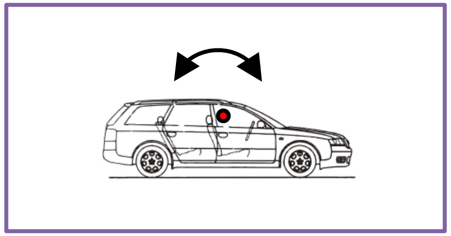
Aircraft Input Signal / **Simulator Response Output**

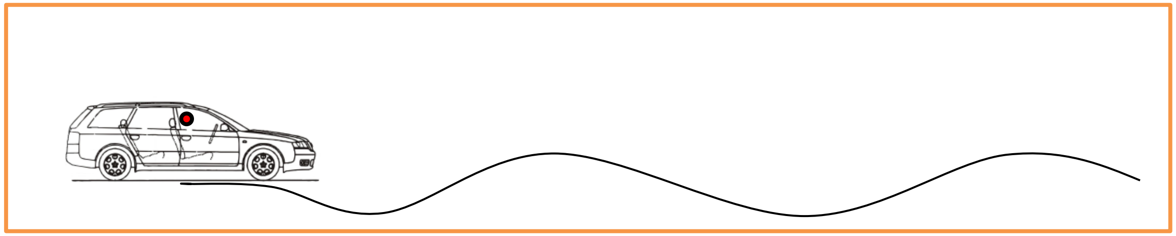
	Roll	Pitch	Yaw	Surge	Sway	Heave
Roll	1a				1b	1c
Pitch		2a		2b		2c
Yaw			3a	3d	3e	3c
Surge		4b		4a		4c
Sway	5b				5a	5c
Heave						6a

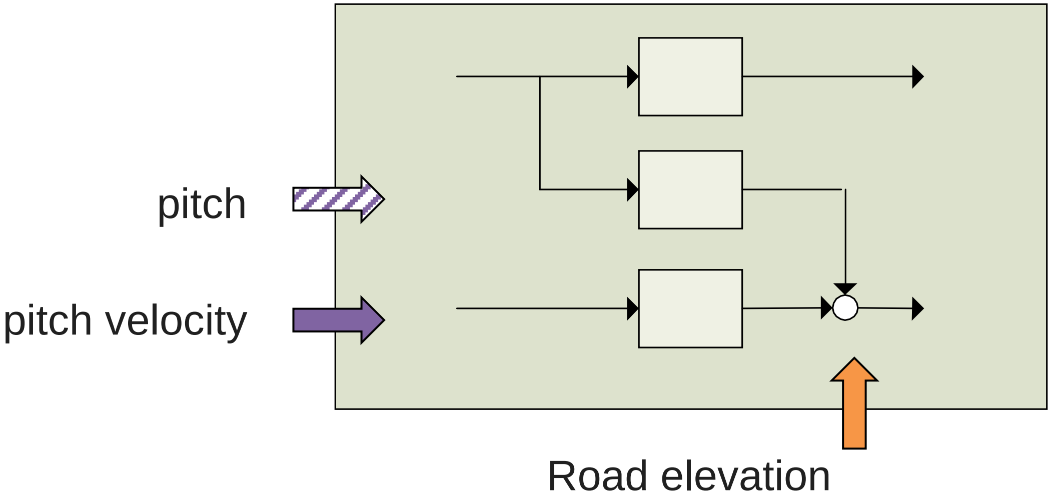
direction motion response
coupled motion response

parasitic motion response due to yaw
parasitic motion response in heave

Roll and Pitch Input

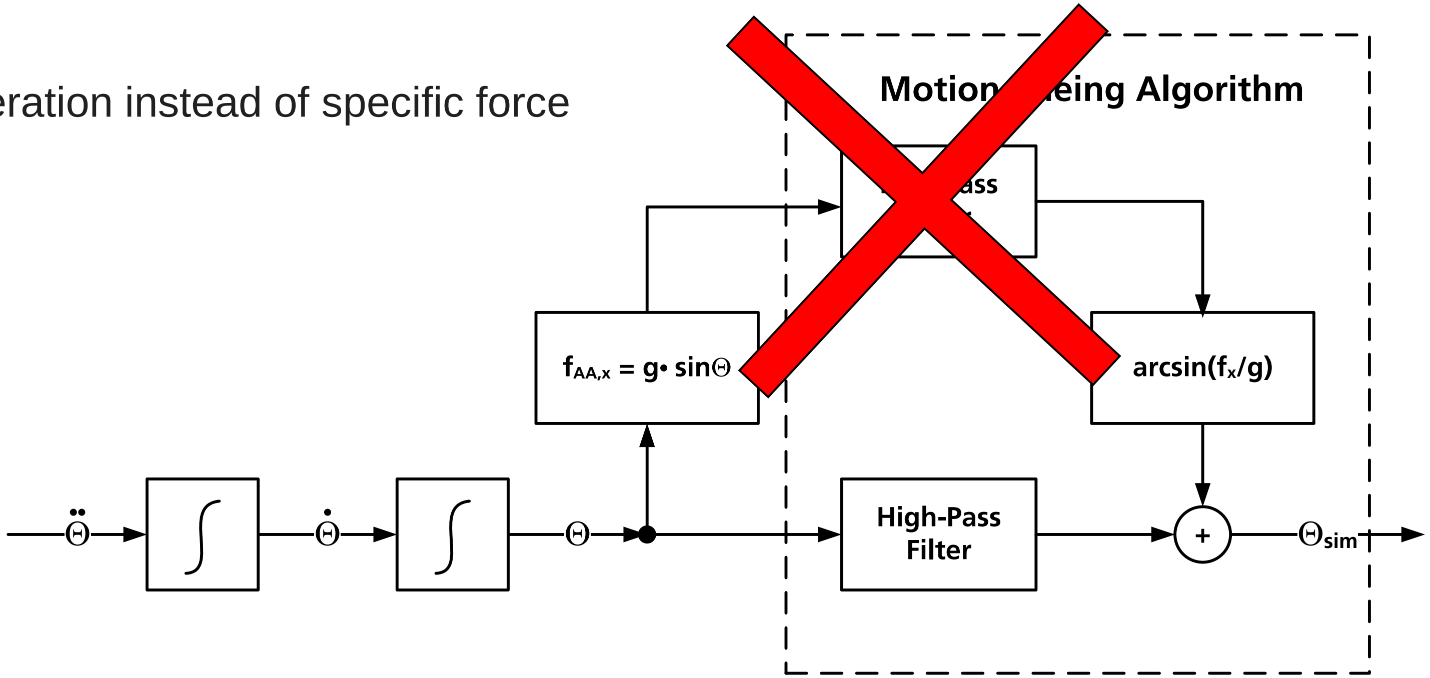






Pitch and Surge Input

Acceleration instead of specific force



Simulator description
Dynamic Driving Simulator (DDS)

Characteristics
- Hexapod moving base (±1.5 m, ±21°, ±1g)
- Wide field-of-view (270° x 40°)
- 18 high-resolution projectors (12000x2000 Pixel)
- 3 mock-ups
  - Modified production car
  - Modulare mock-Up
  - Tram cabin

Areas of Application
- Driving behaviour
- Driver assistance system evaluation
- Human-machine interaction

Simulator description
Robotic Motion Simulator (RMS)

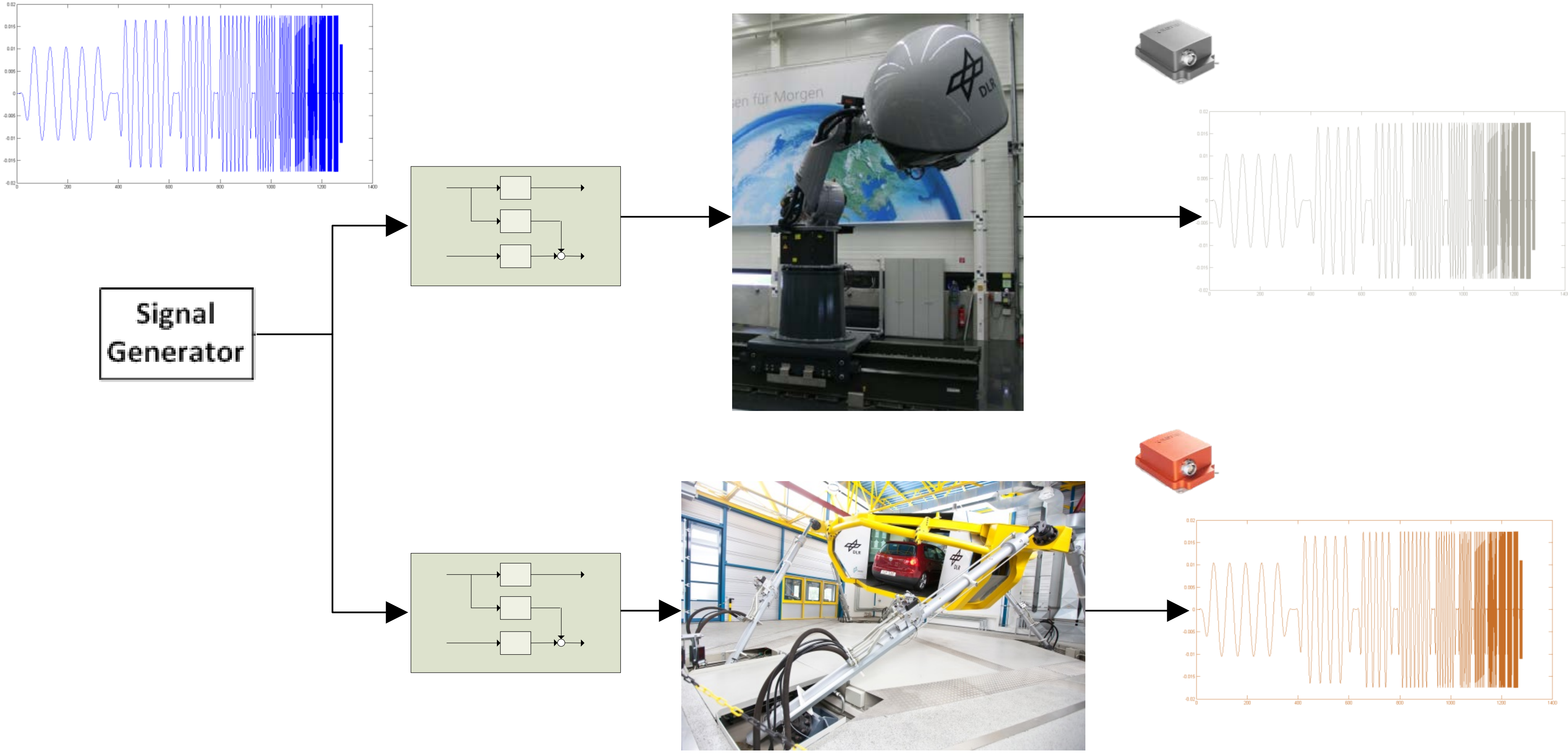
Characteristics

- Industrial robot arm with 6 axes + 1.6 m linear sled system
    - Acceleration up to 0.6g per axis or 1.8g combined
- 2 mock-ups
    - Closed cabin with modular instrument cluster
    - DA42 cockpit with ground-fixed projection screen

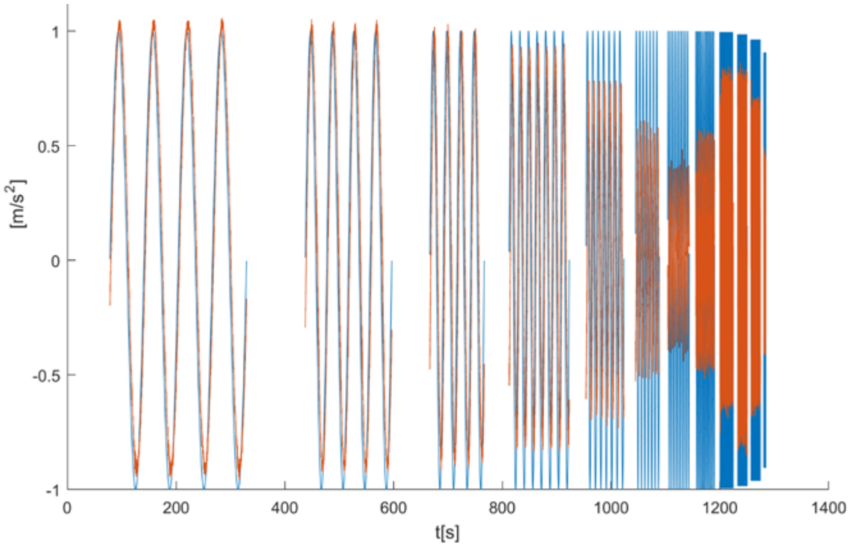
Areas of Application

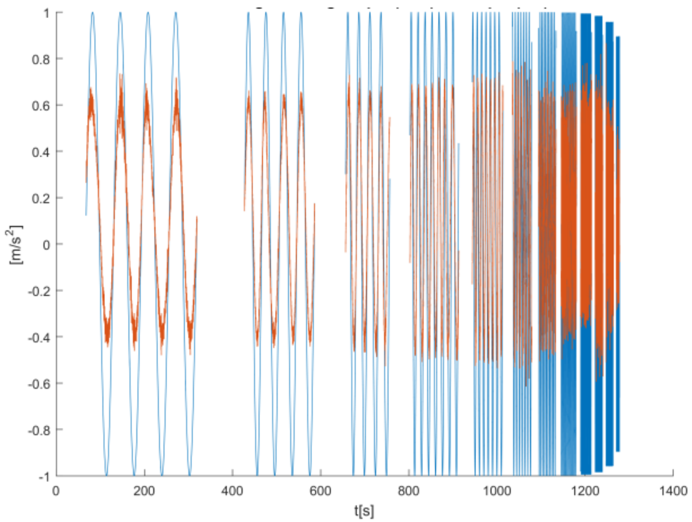
- Flight, automotive and robotics research
    - Driving dynamic simulation
    - Flight training
    - Flight system evaluation
    - Human-machine-interfaces
    - Rapid control prototyping

Measurment set-up

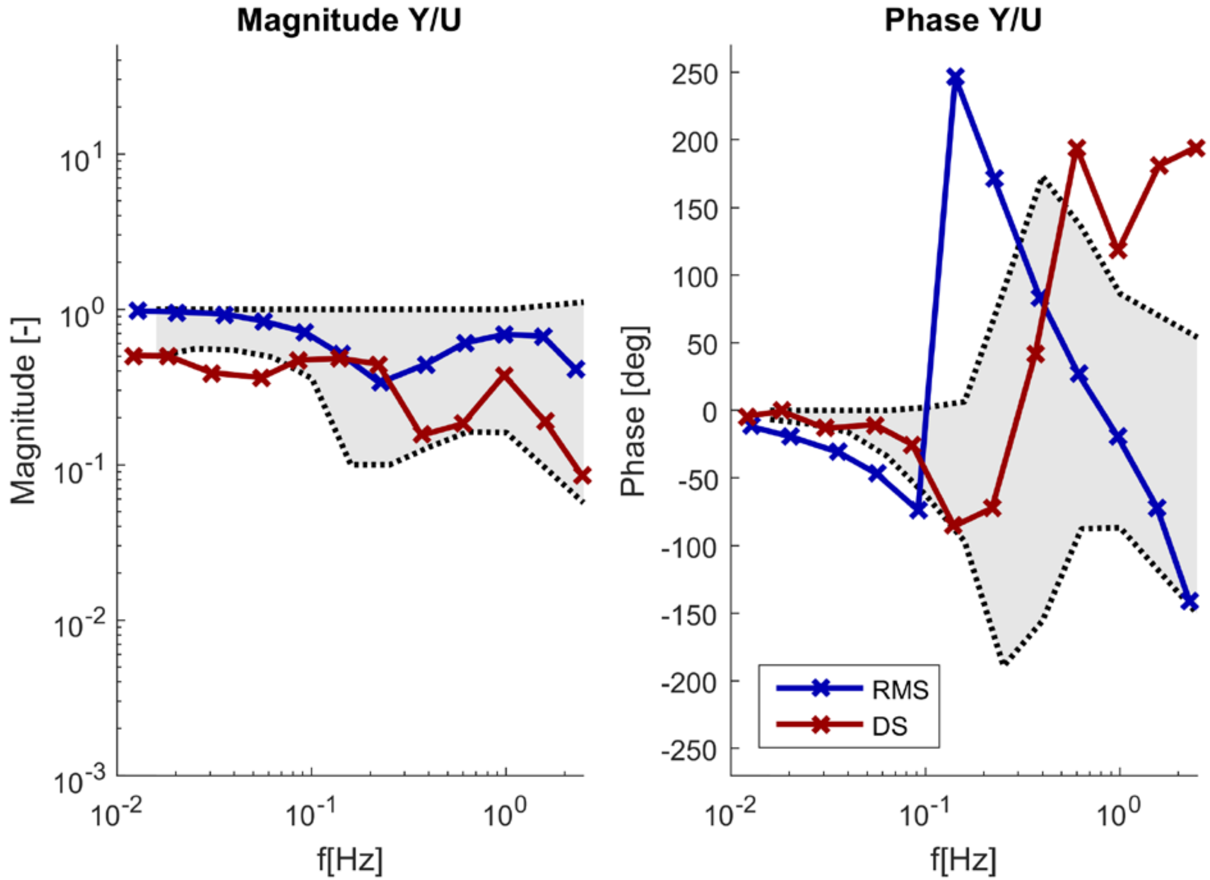


Test 4a – surge response to surge input signal (1/2)

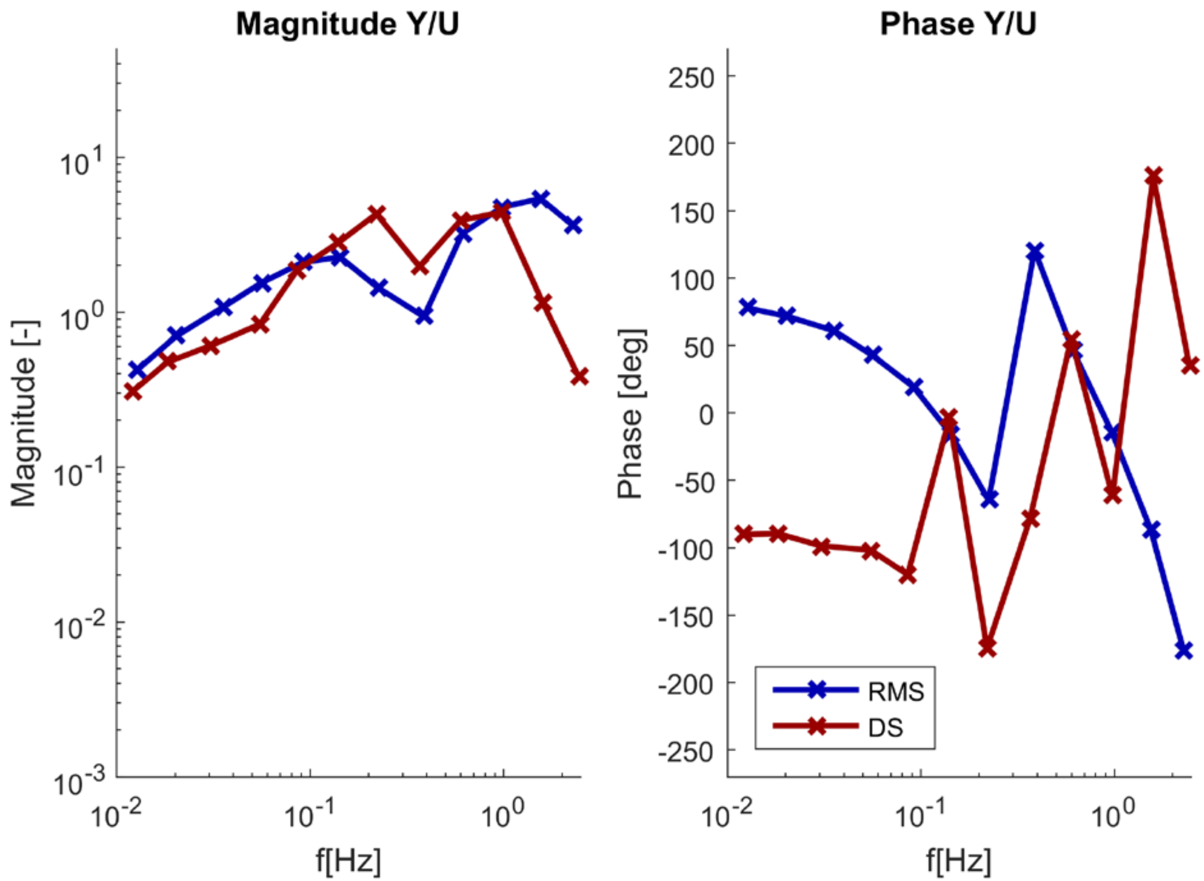




Test 4a – surge response to surge input signal (2/2)

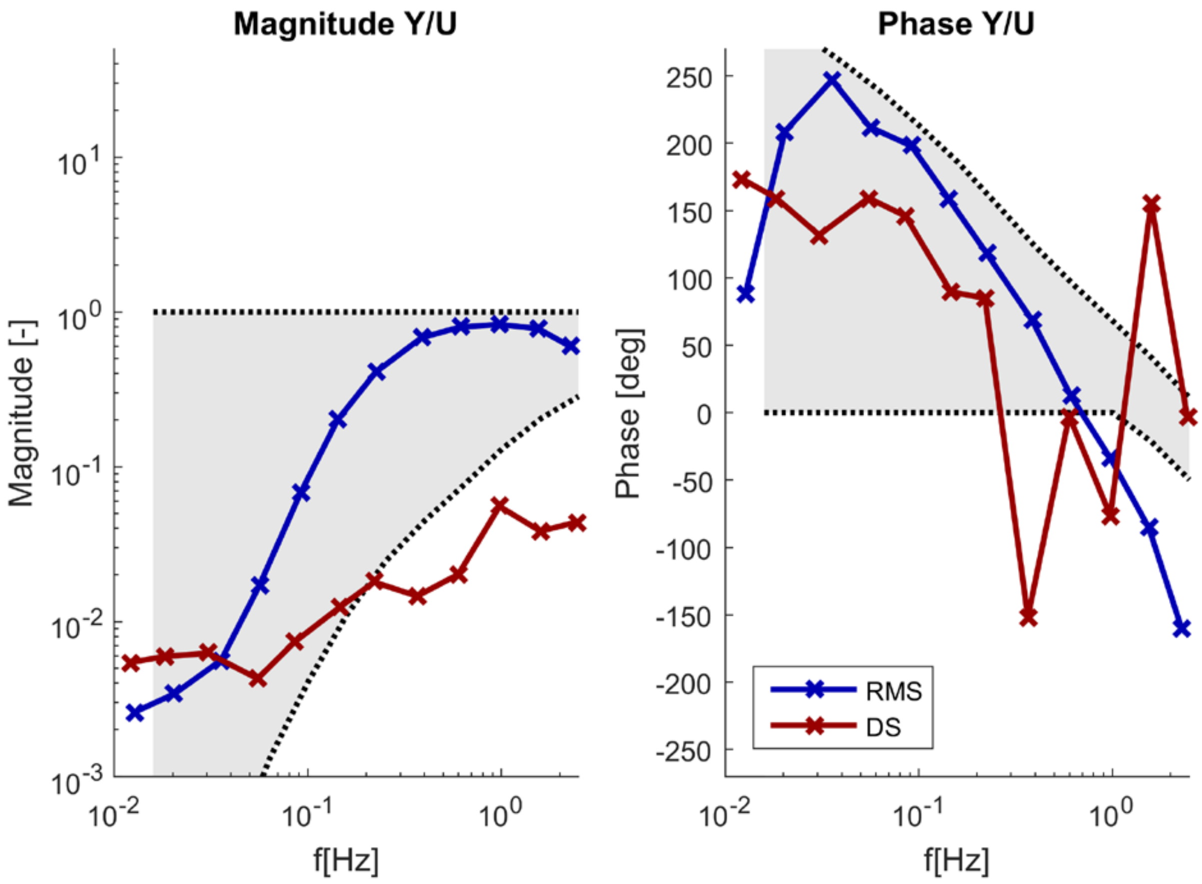


Test 4b – pitch response to surge input signal

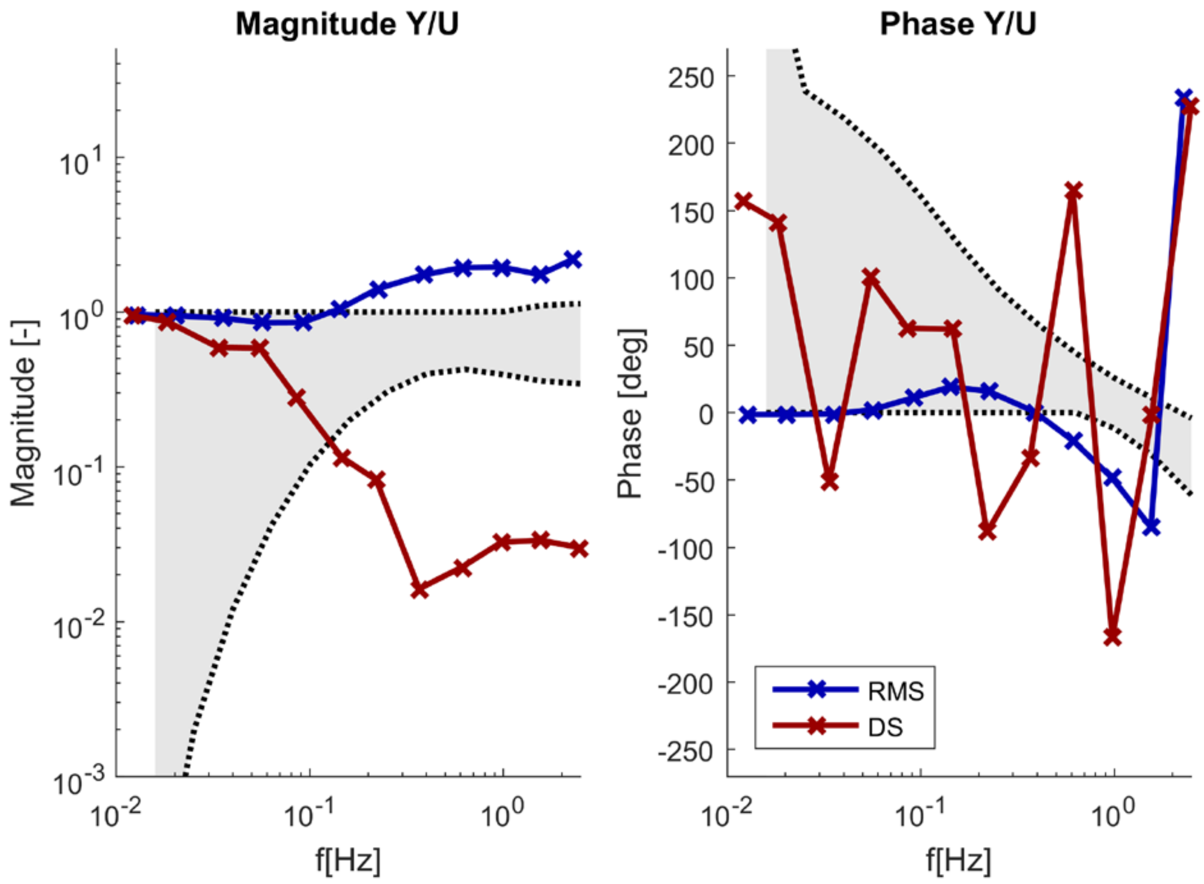


Based on measurements of the angular velocity!

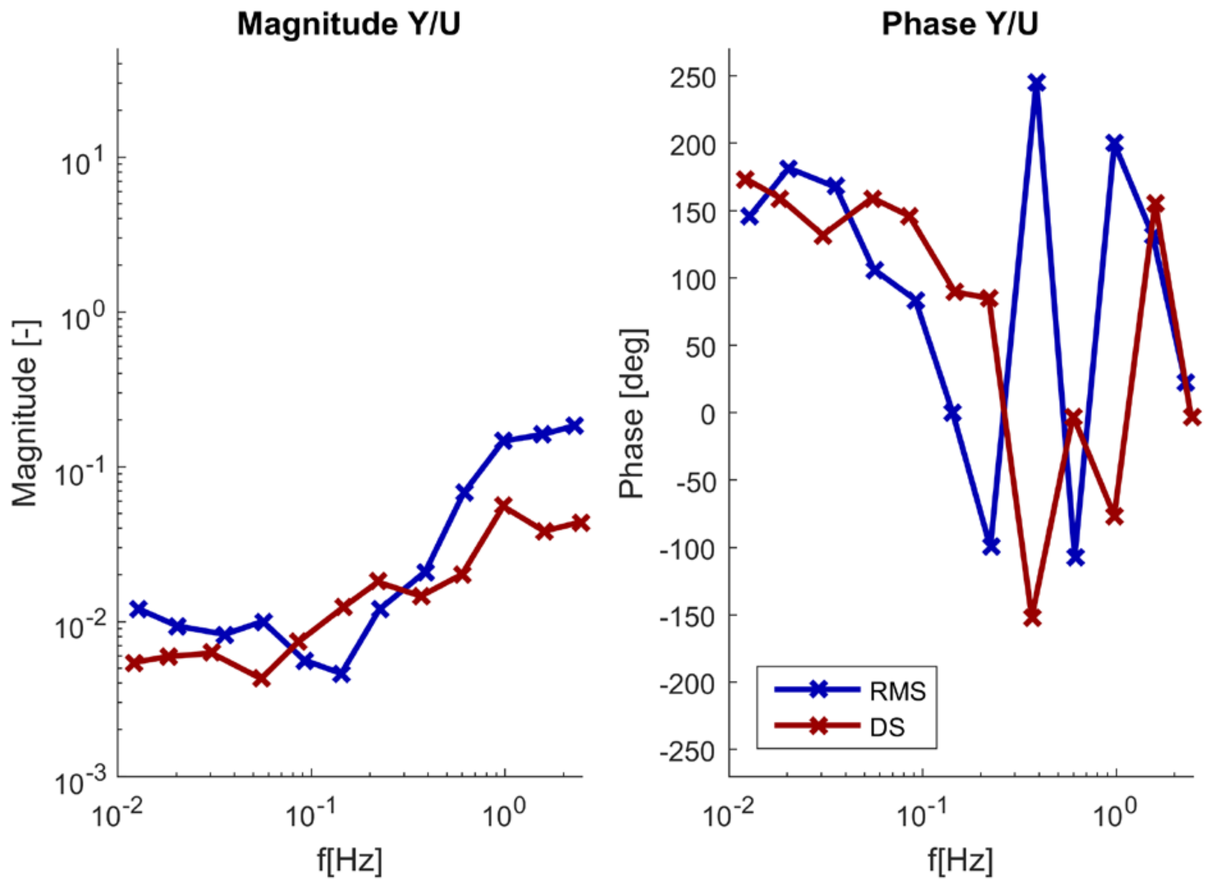
Test 6a – heave response to heave input signal



Test 1a – pitch response to pitch input signal



Test 4c – heave response to surge input signal

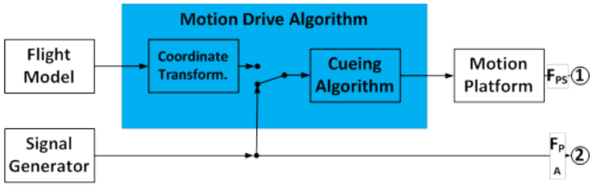


Discussion / Future Plans

- New measurements are planned using
    - Identical measurement equipment in both facilities
        - measuring angles and accelerations
    - Higher overall input gains (signal to noise ratio)
    - Higehr logging frequency
    - Varying motion tunings
    - 2 pitch and roll tests
        - 1 with road slope/elevation variation
        - 1 with vehicle pitch/roll variation

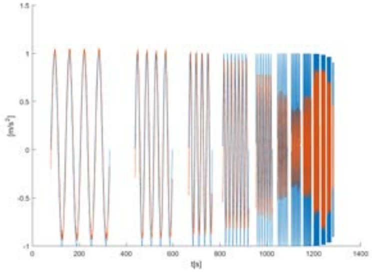
What else should we consider?

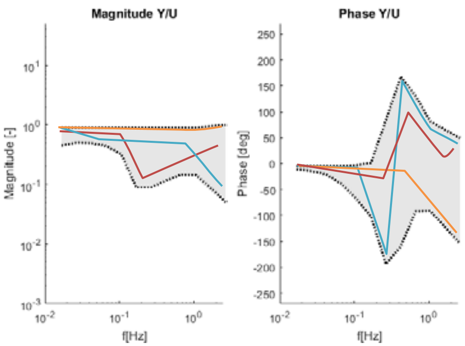
Thank you for your attention!



Questions?

Remarks?





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